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Quantum-Dash Semiconductor Laser Characterization Using Continuous Tuning Optical Swept Source

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Abstract: Device characterization of Quantum-Dash semiconductor mode-locked laser using a continuous tuning swept source is presented. This technique is linear, simple and does not require any prior information about the signal under test.

OCIS codes: (140.4050) Mode-locked lasers; (140.3600) Lasers, tunable; (320.7100) Ultrafast measurements

1. Introduction

Quantum-dash mode-locked lasers can generate picosecond optical pulses at high repetition rates. This makes them suitable for many applications in optical communications including time-division multiplexing, clock recovery and all-optical wave generation. In the recent years, the rapid development of these applications led research to focus on the measurement of the spectral amplitude and phase of the mode-locked lasers to characterize the complex spectrum then recreate the temporal pulse shape. Several techniques have been developed to achieve this measurement such as optical autocorrelation [1], frequency-resolved optical gating (FROG) [2], spectral phase interferometry for direct electric-field reconstruction (SPIDER) [3], Stepped-heterodyne [4] and multiheterodyne [5].

In this work, we promote the use of a linear heterodyne technique using a continuous tuning swept source. This technique requires no prior information about the signal under test. It uses a linear swept source to scan the entire optical spectrum. This permits to cover all spectral components in a single continuous sweep. The signal under test is mixed with the light from the swept source while the beat signal is recorded on a fast oscilloscope. By performing a spectral analysis on the beat signal using a short-time Fourier transform, we can recover the instantaneous beat frequency. By combining this information with the instantaneous frequency of the swept source, we can extract the repetition rate and the number of modes as well as the exact frequency of each mode. Finally, we filter out the beat signal at every time corresponding to an instantaneous frequency lower than half the repetition rate. We can then recover simultaneously the amplitude of all modes as well as the phase difference between consecutive modes. We present experimental characterization of a quantum-dash mode-locked laser operating at a repetition rate of 10 GHz with an optical spectrum consisting of more than 170 modes. This measurement is fast (less than 20 µs) and is adapted to analysis and control of fast signal.

2. Spectral field measurement

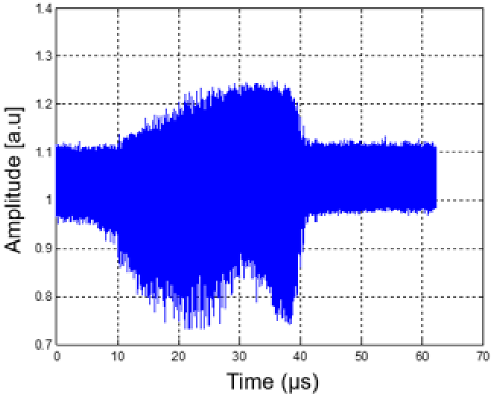

Fig. 1. The beat signal between the swept source and the quantum-dash laser recorded on the real-time oscilloscope.

The experimental setup consists on mixing the signal under test with the light from the swept source and then record the beat signal on the real-time oscilloscope as shown in fig. 1. In this measurement we used a 4 mm long single section quantum-dash mode-locked laser diode operating at a repetition rate of 10 GHz. For the swept source, we used a sampled-grating distributed Bragg reflector (SG-DBR) tunable laser that can linearly scan a 50 nm bandwidth centered at 1550 nm. A relatively fast sweep rate of 20 kHz is adopted. The beat signal is recorded on a real-time oscilloscope with a sampling frequency of 40 GSa/s.

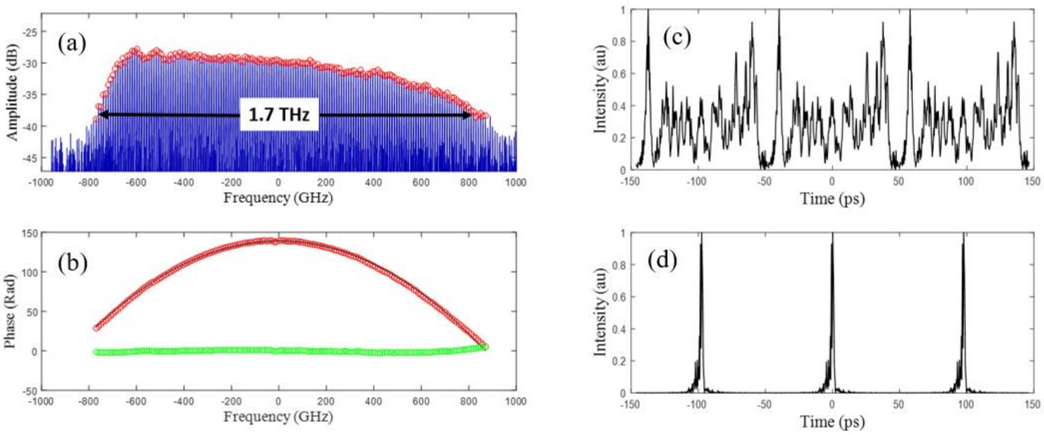

Fig. 2. (a) The spectral amplitude measured using the swept source heterodyne (red circles) and the optical spectrum of the QDash-MLL measured with an optical spectrum analyzer (blue). The spectral width is 1.7 THz at -10 dB. (b) The spectral phase measured (red). The black trace shows the phase profile of 9.31 ps² of quadratic dispersion. The phase profile of the laser after compensating the dispersion (green). (c) The temporal intensity trace of the measured pulse train directly at the output of the QDash-MLL. (d) after 9.31 ps² of quadratic dispersion.

3. Experimental results

Fig. 2. (a, b) show the measurement of the spectral amplitude and phase of the laser. The DC drive current used is 300 mA. The amplitude shows good agreement with the optical spectrum measured with an optical spectrum analyzer (OSA). Due to the strong intracavity dispersion [6] of the quantum-dash mode-locked laser, the spectral phase has a parabolic shape. In order to compensate this dispersion, we introduce a 9.31 ps² of quadratic dispersion. The resulting flat spectral phase after dispersion compensation is plotted in green.

Once the amplitude and phase of all modes is recovered, we can reconstruct the temporal pulse train. Fig. 2. (c, d) represent the reconstructed temporal intensity of the train pulse before and after dispersion compensation. Due to the strong intracavity dispersion, the optical signal is spread out over the entire period as shown in fig. 2. (c). While in fig. 2. (d) we can see a clean pulse train.

4. Conclusion

In conclusion, we have demonstrated spectral field characterization of single section quantum-dash semiconductor mode-locked laser using a continuous tuning swept source. This technique does not require any prior information about the object under test like the repetition rate and the mode frequencies. This has been demonstrated by investigating a quantum-dash mode-locked laser operating at a repetition rate of 10 GHz with an optical spectrum consisting of more than 170 modes. The measurement took less than 20 µs which makes it very suitable for real-time analysis of fast signals.

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